BMP IN BRAZILIAN CITIES – STANDARDIZATION AND APPLICATION

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ABSTRACT: The problems with the floods in large urban centers is a recurring theme for the technical community and, also, one of the greatest challenges, hence the solutions are becoming ever more difficult and expensive than what they would be had there been the presence of planning prior to the occupation. In these metropolis, the main road system is consolidated in the lowland areas along the major rivers, thus resulting in large-scale material losses and in other non-measurable losses as well, such as the loss of lives.

Apart from the impact of the sealing of ground surfaces - in which large volumes are generated over a short period of time - the quality of the water is worthy of regard. In addition to the material carried by the water drag, there is a large amount of contaminating agents, which compromise the treatment and the self-purification of the bodies of water located downstream from these points. In the system of conventional drainage, there is no concern for the reduction of the peak waves and, likewise, for the quality of the water, whilst, in many cases, the problem is pushed on to the smaller-sized municipalities that have no conditions of affording protective measures.

These concerns have led the technical community to rethink the conventional system of drainage and to seek ever more sustainable solutions, with a focus on reducing the massive impact of the storms whilst trying to minimize the concentration of pollutants in the waters. The great challenge lies in the feasibility of deploying those techniques in locations that are densely populated and with few spots available for the implementation of these solutions.

The standardization of the nomenclature and the classification of these methods is proposed, with aims at making them more accessible to the technical community, making them more applicable, and trying to support and disseminate such concepts based on the international bibliography, whilst adapting them to the Brazilian reality.

An example of application with the use of the techniques in a consolidated urbanized area has been provided in an effort to demonstrate solutions which adapt to the midst and, at the same time, promote environmental and urban improvements for the city.

Key Words: Floods. Urban Drainage. Water Resources. Urbanization.

1 INTRODUCTION

Historically, man has always settled in the lowlands along rivers, due to the conditions of an easier relief, to the conditions of soil favorable to agriculture, with more fertile land, and due to the collection of water as well; everything for the survival of man.

With the development of society, “modern” man passed on to settle in the lowlands along the rivers no longer due to survival but rather, and mainly, due to the topographic conditions which allow man to implement arterial road systems or due to the simple ease in casting off the waste of man, with no proper treatment.

As the years pass by, the aggravation of the situation is observed, where the low-income population is only able to maintain inserted in the urban centers by living in slum tenements or shanty towns; otherwise, only the occupation of the periphery of these urban centers is left to that population. In accordance with the latest Demographic Census of 2010, there has been a growth rate in those areas of up to 8%, which passed on to house nearly 30% of the total population. The major concern in that sense is that this occupation of the peripheral areas takes place either by means of legal developments - though with massive earthwork fronts with no proper care at all - or by means of invasions, especially in lots with marked declivity or in the bottoms of valleys. Any of the situations leads to erosion, the carrying of materials with silting of the water streams, and - in the invasion of hillsides - to landslides and the potential risk of lives being lost (SANTOS, A. R., 2012).

In spite of problems like the ones described being known since long, the process of unplanned and technically inadequate urbanization is one of the major challenges faced by the management of rain water, especially in the large urban centers.

If currently, on one hand, there are technologies for the reduction of the high flow peaks, for the minimization of the impact of the debris carried off and of the toxicity of the run-off drained, there is, on the other hand, the political and bureaucratic limitation and the lack of points for the implementation of the measures to improve the quality of water. In that regard, it should be put in evidence that the core of the superficial drainage management consists in the perception of this being pertinent to a problem of allocation of space (CANHOLI 2005, SHEAFFER et al.1982).

2 URBAN ASPECTS OF THE RAIN WATER MANAGEMENT

2.1 Current Scenario

Apart from the concern in reducing the effects of the superficial drainage with the retention of large volumes of water, there should be a concern for the quality of the water which will follow towards the bodies of water.

Constantly, the difficulties do not appear only in the technical arena, for there are countless techniques and highly skilled professionals to find the best solutions coupled to the economic factor, but - unfortunately - the greatest difficulty becomes political.

The support from the public administration has always been a difficult matter, but it should be regarded as one of the central topics of the discussions. As an example of that which is being explained, the situation of the Flood Control Reservoirs (the so-called Big Pools), in operation in the City of São Paulo may be observed. All of them are operated and maintained by the administration o the municipality and, out of the funds destined to their maintenance and conservation for the year 2012, around 700 million Reais, a little more than half of it (approximately 400 million) has been used, with the major part of those resources being used during the rainy season, as a result of the lack of planning in the public bids for the hiring of companies to perform these services. The following picture depicts the 19 (nineteen) big pools in the city and the volumes retained individually.

Then, there is the quest for techniques which are not only better from a point of view of rain water management with retention at a level of lot. There is the need for the implementation of techniques which seek not only the retention of large volumes, but which also take in account the quality of the water to be thrown into the bodies of water. In the face of that need, the techniques known as BMP’s have come to be.

2.2 Diffuse Pollution

The best practices have had their onset as the control, the observance in that which regards the effluents and the waste cast off in the bodies of water and, later on, the control of the then dubbed “diffuse pollution”.

Before the 80’s, it was believed that the pollution of the bodies of water was due to untreated domestic sewer and industrial effluents. Currently, it has been noticed that part of the pollution generated in urban areas is originated in the superficial drainage on impervious areas, areas in the phase of construction, waste dumps or industrial waste sites or the like. The urban drainage systems account for the distribution of those loads and, today, they are known to be important sources of deterioration of rivers, lakes, and estuaries (SMDU, 2012).

Since the compromising of the waters by heavy metals, oil, grease, soil, and other polluting agents is remarkably attributed to the diffuse pollution rather than the concentrated loads from the industries and from the domestic effluents, there is an imperative for action not only in the points of discharge - as had already been foreseen - but, also, there is the need for the implementation of measures which address the basin, as there is no way of pin-pointing an exact location of intervention for the control of that load.

For it to be possible to mitigate such effects occurred sparsely, but which tend to concentrate and become intense as a result of the discharge in the basin, the absorption and the application of the concept of the “Best Management Practices” (BMP) - as they are internationally known - or “Compensatory Techniques” have come to be a necessity.

3 THE INTRODUCTION OF NEW TECHNIQUES

3.1 Overview

The introduction of new techniques for the management of storm waters is, above all, a cultural change. The hygienist practices seem to be conceptually better, as they fend off the problem - at least, so it used to be thought - but, currently, it is perceived that the problem is more actually transferred and the impact is felt by everyone.

Apart from a change in culture for the utilization of techniques which contemplate the abatement of volumes in extreme events, it is fundamental that the qualitative characteristics of the residue waters be observed - so that these waters are discharged in the bodies of water in better conditions and, thus, help in the protection of the water resources whilst allowing for the reduction of the cost of water treatment, for instance.

3.2 The national scenario

The introduction of concepts such as the ones presented beforehand has been carried out with the designated *Medidas Não Convencionais* [Non Conventional Measures] (CANHOLI, 2005), later *Técnicas Compensatórias em Drenagem Urbana* [Compensatory Techniques in Urban Drainage] (BAPTISTA; NASCIMENTO; BARRAUD, 2005), *Medidas de Controle das Inundações Ribeirinhas* [Measures of Control of the Riparian Floods] (TUCCI, 2006), *SUSD - Sistema Urbano Sustentável de Drenagem* [Sustainable Urban System of Drainage] (TOMAZ, 2007), and, finally, *Medidas Ótimas para o Gerenciamento das Cargas Difusas* [Optimal Measures for the Management of Diffuse Loads] (SMDU, 2012) - the latter being a publication of great importance to deal with the subject and widely circulated in the technical midst, developed by the FCTH – *Fundação Centro Tecnológico de Hidráulica* [Technological Center of Hydraulics Foundation], an administration tied to the DAEE – *Departamento de Águas e Energia Elétrica do Estado de São Paulo* [Department of Waters and Electric Energy of the State of São Paulo] and to the POLI - *Escola Politécnica da Universidade de São Paulo* [Polytechnical School of the University of São Paulo].

Figure 1 depicts how those techniques are identified under the vision of the main researchers and/or documents produced on the subject in the national territory.

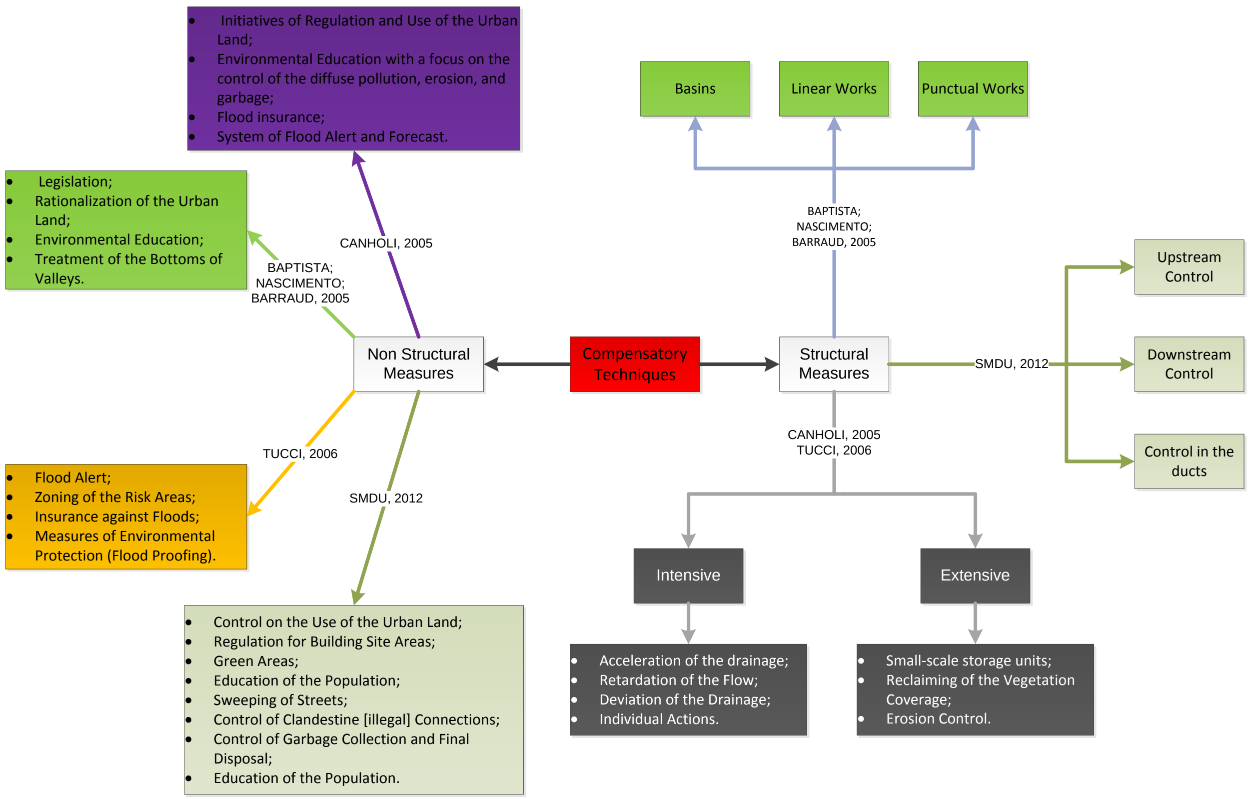

Figure 1. Compensatory Techniques – National Scenario

4 COMPENSATORY TECHNIQUES IN URBAN DRAINAGE

The best management practices or Compensatory Techniques in Urban Drainage or BMP for urban drainage are measures of control adopted to mitigate the shifts in the amount and quality of the urban superficial drainage due to changes in the use of the land. These techniques are introduced with aims at the reduction of the volume of the rain waters, the peaks in flow, and/or minimizing the effects of the sources of diffuse pollution by means of evapotranspiration, infiltration, detention and filtration or chemical and biological actions.

In yet another definition, these techniques are characterized by a set of practices - designed to function as effective - which are likely to minimize the impact of the human activities and development on the quality of water (NVPDC, 1996).

Basically, these techniques are divided in two major groups:

- Non Structural Measures; and,
- Structural Measures.

The division proposed for those measures is presented ahead, whilst using the division above. The non structural measures are divided in three groups:

- Prevention of Pollution

    - ✓ Management of the Use of Urban Land and Public Policy: this subgroup is subdivided in Control of Land Use; Erosion Control; Control of Sediments; Protection of the Waterways; Landscaping Strategies; Urban Reforestation and Restoration of the Riparian Woods; Third-Generation Hydric Balance; and Hydrologic IPTU [Brazilian Urban Territorial and Building Tax].
    - ✓ Education of the Population and Voluntary Measures: Education of the Population; Graffiti of Storm Drain Inlets; Control of Animal Waste; Education and Care for Green Areas and Lawns; and Reduction in Generation of Residue Generated by Automobiles.
    - ✓ Industrial: Use of Pesticides, Herbicides, and Fertilizers; Minimization of Residue - Control in the Source; Organization and Cleaning; Preventive Maintenance; and Prevention of Spill and Response.
- Measures of Control
    - ✓ Sweeping of Streets
    - ✓ Control of Clandestine Connections
    - ✓ Control of the Collection and Final Disposal of Solid Waste
- Mitigating Measures
    - ✓ Flood Proof Construction
    - ✓ System of Prevention and Alert
    - ✓ Zoning of Areas Subject to Floods
    - ✓ Flood Insurance

The structural measures are subdivided in:

- Control in the Source:
    - ✓ Cistern;
    - ✓ Micro-reservoir;
    - ✓ Permeable Pavement Surfaces;
    - ✓ Infiltration Well;
    - ✓ Green Roof.
- Centralized Control:
    - ✓ Wetland;
    - ✓ Detention Basin;
    - ✓ Retention Basin;
    - ✓ Infiltration Basin.
- Linear Control:
    - ✓ Vegetated Channel / Ditch;
    - ✓ Grassy Strips;
    - ✓ Sand Filter;
    - ✓ Rain Garden;
    - ✓ Infiltration Trench.

5 APPLICABILITY IN BRAZILIAN CITIES

To exemplify the use of the techniques presented, an area of analysis located in the municipality of São Paulo, in the region of Butantã, in the Western quadrant of the capital, has been established.

The choosing of the area has been determined by the obtainment of a project for the improvement of the local drainage grid due to the constant flooding in the region. The said project has foreseen the consolidation of the local drainage grid and the expansion of the existing gallery as a solution, resorting to hygienist techniques.

For the analysis, 3 (three) compensatory techniques have been chosen (Green Roofs, Permeable Pavement Surface, and Rain Garden) to be individually deployed and, later on, combined in ways of verifying the reduction of the flow on the account of the implementation of these devices. The selection has been based on techniques which contemplate, as a priority, the scale of the lot, thus identifying a potential for the possibility of participation by the community. Additionally, a linear technique has been selected for the waters of the road system.

5.1 Data and Criteria of the Project

The elements of the project are presented below. For a comparative analysis, the same project criteria have been used both in the equations as in the flow of the basins.

5.2 Localization of the Area

The area studied lies in the City of São Paulo, in the Western quadrant, more precisely, in the district of Butantã. The image ahead presents the boundaries of the basin of study in "yellow", the rain gardens in "green", the permeable pavement surfaces in "blue", and the green roofs in "orange",

Figure 2. Proposal of Utilization of Compensatory Techniques

The table 1 depicts the area covered by each one of the techniques selected for the study.

Compensatory Technique	Area Used (ha)
Rain Garden	0.16
Permeable Pavement Surface	1.39
Green Roof	3.75

Table 1. Areas used by the Compensatory Techniques

5.3 Criteria and Parameters

5.3.1 Pluviometric Intensity

The project has used the equations of intense rains developed by the Engineers Francisco Martinez and Nelson Luiz G. Magni for the City of São Paulo, as presented below:

$$i_{t,T} = 39{,}30147(t+20)^{-0{,}92281} + 10{,}17667(t+20)^{-0{,}87641}\left[-0{,}46532 - 0{,}84067 \times In \times In(T/T-1)\right] \quad [1]$$

Where: it, T = intensity of the rain, corresponding to the duration "t" and the period of return "T" (mm/min); t = duration of the rain (min); and, T = period of return (years).

5.3.2 Calculation of Flow, Concentration Time and Period of Return

Currently, the formula most widely used for the project of drainage is that of the rational method, recommended for basins that are homogeneous and small in dimension. It is represented by the following equation:

$$Q = \frac{C \cdot I \cdot A \cdot D}{6} \quad [2]$$

Where: Q = peak flow (m^3/s); C = coefficient of superficial drainage (non dimensional); I = mean intensity for the duration and recurrence considered (mm/min); A = area de contribution (ha); and, D = coefficient of rain distribution.

The figures of the coefficient of superficial drainage (C) for deployment of the Rational Method have been oriented by the data from the table presented ahead.

Based on the local directives, the coefficient of superficial drainage must be calculated as a function of the Period of Return of the project in accordance with the formula below:

$$C_T = 0{,}8 \cdot T^{0{,}1} \cdot C_{10} \quad [3]$$

Where: CT = coefficient of superficial drainage for the period of return T (years); C10 = coefficient of superficial drainage for the 10-year period of return; and, the C10 coefficient being adopted as C10 = 0.60.

For this study, TR = 25 has been adopted, which resulted in CT = 0.66. An identical calculation must be carried out for the determination of the coefficients for the other periods of return. For the analysis, there has been a comparison between the results for the Period of Return for TR = 25 years. However, the periods of return for TR = 10, 50, and 100 years are also presented.

For the concentration time, the Kirpich's formula - widely disseminated in the technical midst - has been used.

5.4 Case Study

The study has been based on a real project of retrofitting a drainage grid in the region of Butantã, in the Western quadrant of the capital of São Paulo. To that purpose, three compensatory techniques have been proposed for deployment in the region. Based on the data from the item 5.2, it has been admitted the hypothesis that the devices proposed will be disconnect from the grid, that is, they will cease to contribute. Initially, the area disconnected in the existing project has been designated as follows.

- Total Area of the Basin – A = 13.24 ha;
- Total area of the techniques proposed – A = 5.30 ha (40%);

For a means of comparison of the techniques were attributed, those techniques have been related to coefficients of superficial drainage, in ways that the flows be recalculated proportionally. In that sense, four cases have been analyzed, being: one for each technique and, in addition, the global use of the same has been taken into account (combined techniques). The table below presents the recalculated coefficients.

Compensatory Technique	Area used (ha)	C
Rain Garden	0.16	0.59
Permeable Pavement Surface	1.39	0.49
Green Roof	3.75	0.32
Combined Techniques	5.30	0.20

Table 2. Determination of the Coefficient of Proportional Superficial Drainage

Based on the previous information, the project flows have been recalculated and compared to the original project. The results are depicted in the Table 3.

Technique	FLOW (m^3/s)			
	10 years	25 years	50 years	100 years
Original Project	2.46	3.18	3.77	4.44
Rain Garden	2.42	3.13	3.71	4.36
Permeable Pavement Surface	2.01	2.60	3.08	3.62
Green Roof	1.31	1.70	2.01	2.37
Combined Techniques	0.82	1.06	1.26	1.48

Table 3. General Table of Flows

6 CONCLUSIONS

The compensatory techniques of urban drainage - in a more widely accepted nomenclature in Brazil - involve structures and concepts which are already disseminated in developed countries and which are beginning to take shape and earn space among the national technicians and researchers, aiding in the dissemination of knowledge.

Two divisions have been proposed here - that are practically unanimously regarded throughout the entire technical midst - which is: the treatment of the techniques in structural and non structural. In that sense, there is an entity which classifies the vegetative controls (channel and ditch in grass, for example) as non structural measures. There has been the classification in structural and non structural measures as a means to avoid the dissemination of terminologies and techniques, with aims at standardizing the concepts already punctuated by the Brazilian researchers of greatest renown.

These classifications have been used to select and analyze an area that is already densely urbanized, and to verify the potential reduction of the volume drained. However, the analyses have not been carried out in depth pursuant to the criteria for the removal of residue and chemical compounds.

By the criteria used, there is the verification, for a Period of Return of 25 years, of reductions between 2 and 47% for each technique individually, or of a reduction of 67% with the use of the techniques combined.

It must be highlighted that the analysis has been carried out considering the maximum potential of utilization and that, in the case of green roofs, not all of the covers are liable to treatment for the adoption of the technique - be that due to technical impediment or by matters of cost.

The permeable pavement surfaces have been adopted in private areas, for that kind of pavement must not be used in areas of heavy traffic and, in this way, they have been considered for the areas of vehicle parking. Another point which deserves a comment is the classification of the permeable pavement surfaces. BAPTISTA; NASCIMENTO; BARRAUD, 2005 classify the pavement as linear works and TOMINAGA, 2013 classifies as a measure of control in the source and, even if both classifications make sense, the classification as a control in the source is more acceptable due to the limitations for the use of these coatings, making them great for vehicle parking areas, but not recommendable for the road system, in which they would be classified as linear.

The rain gardens have been adopted along an avenue with a large central courtyard, and the restriction to its implementation will take place by the manholes in the location, and the grids of gas, water, and sewer, plus large sized vegetation, for example.

It must be observed that the fact of implementing these techniques will not provide, in many cases, for the elimination of the conventional system.

One of the points which particularly draws more attention is the general concern with the reduction of the rain peak but, at the same time, there is no concern with the quality of the water, making the entire process cheaper and easier, should it begin within the lot.

Finally, it should be pointed out that, regardless of how good a technical solution may be, the support from both the public administration and the community is fundamental for the correct operation of these devices, hence the maintenance costs of the same must be foreseen with aims at their correct functioning.

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